90 Rec'd PCT/PTO 07 SEP 2000

FORM PTO-1390 (REV 5-93) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		ATTORNEY DOCKET NO. 108149-00000 DATE: September 7, 2000 U.S. APPLN. NO. (IF KNOWN, SEE 37 CFR 1.5) 09/622924
INTERNATIONAL APPLICATION NO. PCT/GB99/00573	INTERNATIONAL FILING DATE 5 March 1999	PRIORITY DATE CLAIMED 7 March 1998

TITLE OF INVENTION: EXTRACTING POWER FROM MOVING WATER

APPLICANT(S) FOR DO/EO/US: Timothy William GRINSTED, Michael John WATCHORN

1. XX This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
   (THE BASIC FILING FEE IS ATTACHED)

2. _ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.

3. XX This express request to begin national examination procedures (35 U.S.C. 371(f) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT articles 22 and 39(1).

4. XX A proper demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.

5. XX A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. XX is transmitted herewith (required only if not transmitted by the International Bureau).
   b. XX has been transmitted by the International Bureau.
   c. _ is not required, as the application was filed in the United States Receiving Office (RO/US)

6. _ A translation of the International Application into English (35 U.S.C. 371(c)(2)).

7. XX Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. XX are transmitted herewith (required only if not transmitted by the International Bureau).
   b. _ have been transmitted by the International Bureau.
   c. _ have not been made; however, the time limit for making such amendments has NOT expired.
   d. _ have not been made and will not be made.

8. _ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).

9. _ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).

10. _ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. XX An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

12. _ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13. XX A FIRST preliminary amendment.
    _ A SECOND or SUBSEQUENT preliminary amendment.

14. _ A substitute specification.

15. _ A change of power of attorney and/or address letter.

16. XX Other items or information: PCT/IPEA/416, PCT/IPEA/409, PCT/ISA/210, PCT/IB/304, PCT/IB/308, PCT/IB/332, PCT/IPEA/401, PCT/RO/101
    CHECK NO. 300302
    13 Sheets of Formal Drawings

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U.S. APPLN. NO. (IF KNOWN, SEE 37 C.F.R. 1.50) 09/622924	INTERNATIONAL APPLICATION NO. PCT/GB99/00573	ATTORNEY DOCKET NO. P108149-00000 DATE: September 7, 2000	
17. XX The following fees are submitted: **Basic National Fee (37 CFR 1.492(a)(1)-(5):** Search Report has been prepared by the EPO or JPO..............................$840.00 International preliminary examination fee paid to USPTO (37 CFR 1.482)...$670.00 No international preliminary examination fee paid to USPTO (37 CFR1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2))....................$760.00 Neither international preliminary examination fee (37 CFR 1.482) or international search fee (37 CFR 1.445(a)(2)) paid to USPTO..$970.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) ....$ 96.00		CALCULATIONS	PTO USE ONLY

ENTER APPROPRIATE BASIC FEE AMOUNT =				$840	
Surcharge of $130.00 for furnishing the oath or declaration later than _ 20 _ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$00	
Claims	Number Filed	Number Extra	Rate		
Total Claims	44 - 20 =	24	X $ 18.00	$432	
Independent Claims	01 - 3 =	00	X $ 78.00	$00	
Multiple dependent claim(s) (if applicable)			+ $260.00	$00	
TOTAL OF ABOVE CALCULATIONS =				$1,272	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).				$00	
SUBTOTAL =				$1,272	
Processing fee of $130.00 for furnishing the English translation later the _ 20 _ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$00	
TOTAL NATIONAL FEE =				$1,272	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$00	
TOTAL FEES ENCLOSED =				$1,272	
				Amount to be refunded	$
				Charged	$

a. XX A check in the amount of $1,272 to cover the above fees is enclosed.
b. _ Please charge my Deposit Account No. 01-2300 in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.
c. XX The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 01-2300 .

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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09/622924

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Timothy William GRINSTED et al

Serial No.: Unknown

Filed: September 7, 2000

For: EXTRACTING POWER FROM MOVING WATER

PRELIMINARY AMENDMENT

Commissioner of Patents
Washington, D.C. 20231

September 7, 2000

Sir:

Prior to calculation of the filing fee and prior to the examination of this application, please amend the above-identified application as follows:

IN THE CLAIMS:

Claim 3, line 1, delete "or 2".

Claims 5, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17,18, and 19, line 1 of each, delete "any proceeding claim" and insert therefor --claim 1--.

Claim 6, line 1, delete "4 or 5".

Claim 22, line 1, delete "or 21".

Claim 23, lines 2 and 3, delete "any preceding claim" and insert therefor --claim 1--.

Claim 25, line 1, delete "or 24".

Claim 26, line 1, delete "any of claims 23 to 25" and insert therefor --claim 23--.

Claim 28, line 1, delete "any of claims 23 to 27" and insert therefor --claim 23--.

Claims 29 and 30, line 1 of each, delete "any of claims 23 to 28" and insert therefor --claim 23--.

Claim 31, line 1, delete "any claims 23 to 30" and insert therefor --claim 23--.

Claim 32, line 1, delete "any of claims 23 to 31" and insert therefor --claim 23--.

Claim 33, line 1, delete "any of claims 23 to 32" and insert therefor --claim 23--.

Claim 37, line 1, delete "or 36".

Claim 38, line 1, delete "any of claims 36 to 37" and insert therefor --claim 36--.

Claim 39, line 1, delete "any of claims 35 to 37" and insert therefor --claim 35--.

Claim 40, line 1, delete "any of claims 34 to 39" and insert therefor --claim 34--.

Claim 41, line 1, delete "any of claims 33 to 39" and insert therefor --claim 33--.

Cancel claims 45-47 without prejudice.

REMARKS

The above amendment to the claims has been made to correct the multiple dependency of the claims and to put the application in better condition for examination.

In the event that any fees are due in connection with this paper, please charge our Deposit Account No. 01-2300.

Respectfully submitted,
ARENT FOX KINTNER PLOTKIN & KAHN PLLC

Robert B. Murray
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Reg. No. 22,980

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SMALL ENTITY DECLARATION

APPLICANT OR PATENTEE GRINSTED et al

SERIAL NO. ____ ☐ PATENT NO. ____ ATTORNEY'S DOCKET NO. P108149-00000

☒ 1. FILED OR ISSUED

☐ 2. SUBMITTED HEREWITH

FOR : EXTRACTING POWER FROM MOVING WATER

I (we) hereby declare that I (we) am (are) entitled to the benefit of small entity status with respect to the above-identified application or patent for purposes of paying reduced fees under 35 U.S.C. §§41(a) and (b) to the U.S. Patent and Trademark Office.

☐ A. **INDEPENDENT INVENTOR**
I (we) qualify as (an) independent inventor(s) as defined in 37 C.F.R. §1.9(c).

☐ B. **INDIVIDUAL NON-INVENTOR**
I (we) would qualify as (an) independent inventor(s) as defined in 37 C.F.R. §1.9(c) if I had made the invention.

☒ C. **SMALL BUSINESS CONCERN**
I am ☐ THE OWNER ☐ AN OFFICIAL of the small business concern identified below and am empowered to act on behalf of the concern. The concern qualifies under 37 C.F.R. §1.9(d) and 13 C.F.R. §121.3-18. Rights under contract or law have been conveyed to and remain with the concern and are exclusive unless a checkmark is placed here ☐. All other rights belong to small entities as defined in 37 C.F.R. §1.9.

☐ D. **NON-PROFIT ORGANIZATION**
I am an official empowered to act on behalf of the non-profit organization identified below. The organization qualifies under 37 C.F.R. §1.9(e), subsection: ☐ (1) ☐ (2) ☐ (3) ☐ (4). Rights under contract or law have been conveyed to and remain with the organization and are exclusive unless a checkmark is placed here ☐. All other rights belong to small entities as defined in 37 C.F.R. §1.9.

I (we) acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate [37 C.F.R. §1.28(b)].

I (we) declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

A. INDEPENDENT INVENTORS(S) B. INDIVIDUAL NON-INVENTOR(S)

Name	Signature	Date

C. BUSINESS CONCERN D. NON-PROFIT ORGANIZATION

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By M. J. WATCHORN
Name of Person Signing

M S Watc
Signature

Production Director
Title

15-9-00
Date

Rev. #3, October 1994

EXTRACTING POWER FROM MOVING WATER

Background of the Invention

This invention relates to a prime mover, an apparatus and method for extracting power from moving water such as tidal flows and river currents.

Hitherto, this has generally been proposed or achieved by means of turbines analogous to underwater windmills. The blades of these windmills rotate as a result of the water flow about a horizontal or vertical axis at low speeds of the order of 10 to 30 revolutions per minute and at high torque. Gearboxes are required to transfer rotation at such speeds to the high speeds required for electrical generators. The gearboxes are large, complex and expensive with high power losses. The gearboxes also suffer from reliability problems and are difficult to maintain, particularly when located under water.

GB1604372 discloses a device for utilising tidal energy which comprises two cylindrical tank members fitting slidably inside one another. The device is supported on a tripod resting on the seabed. A flotation collar renders the outer tank buoyant so that it rises and falls with the water level as a result of which air within the tanks is compressed by their relative movement. Connections provided in the cover of the inner tank allow the compressed air to be used to drive an air turbine situated at a remote location.

The current invention aims to provide a prime mover (for converting natural energy into mechanical power), an

apparatus and a method for transferring kinetic energy from slow moving water. The prime mover can be used with any suitable energy removal scheme. For example it can be used to produce electrical energy directly or to provide a useful form of mechanical movement. In a further aspect of the invention, kinetic energy from slow moving water is transferred into kinetic energy of a fluid travelling at high speed. Preferably the fluid is air.

According to a first aspect of the invention there is provided a prime mover for extracting power from moving water comprising a body which is caused to oscillate relative to the water by reversing the direction of thrust generated by at least one submerged control member protruding from a side of the body.

Whilst this prime mover is ideally suited for extracting energy from flowing water, extraction from other flowing fluids is possible and the term "water" should be interpreted as covering other flowing liquids and gases throughout this document.

Preferably, at least one control member protrudes from each side of the body.

Preferably, the shape of the body is such that water is caused to travel faster over a portion of the surface of the body and in which one or more protruding control members are positioned at that portion of the surface of the body.

Preferably, the body comprises curved sides which orientate the body with respect to a flow of water so

that the control member or members are substantially perpendicular to the direction of flow of the moving water.

Preferably, the control member(s) is generally planar.

Preferably, the shape of the sides is symmetrical.

Preferably, the sides of the body are convex.

Preferably, at least one second protruding control member is provided fixed with respect to the body and arranged so that when the direction of thrust of a first reversible protruding control member is reversed, the angle of the second fixed control member with respect to the flow of water is altered so that the action of the water on that second fixed member. Thus the control member acts like a tail plane of an aircraft.

Preferably, the fixed second control member is positioned at a point on the body at which the velocity of the water flowing past the body is at or near a maximum.

Preferably, the first reversible control member is spaced laterally from it in the direction of the water flow. Preferably, the reversible control member is downstream of the fixed control member. This is much like a tail plane on an aircraft.

Preferably, one or more control members comprise hydroplanes whereby the direction of thrust is reversed by reversing the angle of inclination of at least one hydroplane.

Preferably, the distribution of control members on

opposing sides of the body is symmetrical.

Preferably, the body is elongate and tends to orientate itself so that it is elongate in the direction of flow of the current.

Preferably, the body oscillates in a vertical direction.

Preferably, one or more reversible controls members are pivotable in its entirety.

Preferably, one or more reversible control member are pivotable about an edge protruding from the body.

Preferably, one or more reversible control members are pivotable about a central axis protruding from the body.

Preferably, one or more of the reversible control members are formed by a pivotable flap mounted to a control member or other mounting means fixed with respect to the body.

Preferably, one or more reversible control members have an aerofoil shape.

In a further embodiment, one or more control members comprise a rotatable cylindrical structure whose direction of rotation can be reversed to generate a change in direction of thrust. As an example, the cylindrical structure may form a continuous cylinder or may have spaced vanes.

Preferably, more than one control member is provided on opposing sides of the body.

Preferably, the control members are spaced along the body

in a direction substantially perpendicular to the direction of flow of the water when the body is orientated so that its control members protrude from the body in a direction substantially perpendicular to the direction of flow of water.

Preferably, the body is arranged to oscillate vertically and two or more control members are provided on opposing sides of the body spaced in a substantially vertical line.

Preferably, three or more control members are provided on each side and the separation of the control members is substantially equal.

According to a further aspect there is provided, apparatus for extracting power from moving water comprising a prime mover as described herein.

Preferably, the prime mover is connected to mooring means secured or securable under water.

Preferably, the prime mover is connected to mooring cable.

Preferably, the prime mover is axially slidably mounted or mountable to a column secured or securable under water in an upright position.

Preferably, the prime mover comprises a downwardly extending tube which surrounds the column.

Preferably, power conversion means are provided for converting the oscillations of the prime mover into another form of power such as electrical power.

Preferably, the prime mover is submerged when generating power.

Preferably, power conversion means are provided comprising one or more hydraulic pumps, a crank for generating mechanical rotation or means for generating electricity such as an electric coil and magnet.

Preferably, power conversion means are provided comprising a fluid pump for pumping fluid to a higher level.

Preferably, the apparatus is moored to or mounted on a structure such as column on which apparatus for extracting power from wind or wave is mounted. Thus, the prime mover extracts power from tidal or river current flow, and power is also extracted from wind or waves. Whilst the prime mover is ideally suited to extracting power from tidal and river currents, it is also adaptable to be used for extracting power from waves as will be explained below in connection with a preferred embodiment.

Preferably, the prime mover is buoyant. Typically, it will float on the surface with part of its structure below the surface.

Preferably, the prime mover comprises an open bottomed tank which when it oscillates alternately compresses and decompresses a fluid inside it between a closed top of the tank and the water surface.

It will be understood by those skilled in the art from the information disclosed herein that the inventions in

this preferred embodiment can operate in two modes.

In the first mode, power is extracted from tidal and river flows in the following way. As water flows past the control member, upward and downward thrust is produced causing the prime mover to move in a plane which crosses the flow direction (typically it is roughly perpendicular). Reversing the control member causes the direction of thrust to be reversed and when this is repeated the prime mover reciprocates generally in the plane.

This reciprocating movement can be converted into a more useful form of energy by an appropriate energy removal arrangement. In this preferred embodiment the prime mover is a tank which alternately compresses and decompresses a fluid.

In the second mode, power is extracted from waves. As waves impinge on the tank, the water level inside it rises and falls relative to the top of the collector. Vertical movement of the tank is damped by the drag of the hydroplanes. This drag can be supplemented, though this is not always necessary, by reversing the control member or members to produce thrust in a direction opposite to the rise and fall of water in the waves. Thus the tank tends to remain stationary relative to a fixed point, the shore or sea bed say, but the fluid inside the tank is alternately compressed and decompressed by the action of the waves.

Preferably, at least one duct in the top of the tank permits the fluid alternately to flow out of and into the

tank.

Preferably, the fluid flowing through one or more ducts drives a turbine. Preferably, the turbine is mounted on the tank. Thus, the turbine operates in air when the fluid chosen is air. Preferably, the turbine is directly drivably connected to an electrical generator. Preferably, the number and/or size of ducts open at any time, or selected to drive a selected turbine at a particular time, can be varied so that the flow of air can be optimised to the efficiency requirements of the turbine.

Preferably, a turbine is housed in a duct. Preferably, a generator, or combined turbine and generator is housed in the duct.

Preferably, the turbine rotates in the same direction irrespective of the flow of fluid out of or into the tank.

Preferably, valve means are provided so that fluid passes through the turbine in the same direction irrespective of the flow of fluid out of or into the tank.

Preferably, the fluid is air.

In a further aspect there is provided a method of extracting power from moving water comprising repeatedly reversing the direction of thrust generated by a submerged control member protruding from a body in a prime mover as described herein.

Preferred embodiments of the invention will now be described, by way of example only, with reference to the

accompanying drawings as follows:

Figure 1 is a perspective view of an active water column apparatus installed in working position for extracting power from moving water.

Figure 2 is a plan view of the apparatus of Figure 1.

Figure 3 shows eight cross-sectional views (A-H) showing the operating cycle of the apparatus.

Figure 4 is a graph showing hydroplane movement, air pressure and hydroplane acceleration as a function of time during the operating cycle.

Figure 5 shows a number of repeated cycles similar to those in Figure 4.

Figure 6 is a plan view of an alternative embodiment of the invention showing several air exhaust/inlet ducts.

Figure 7 is a cross-sectional view through the apparatus of Figure 6 showing its mooring on a monopile.

Figure 8 shows plan and cross-sectional views of a cable moored apparatus.

Figures 9A and 9B shows cross-sectional views through alternative hydroplanes of the apparatus in accordance with the invention.

Figure 10 is a schematic elevation view of one side of an apparatus according to the invention showing fixed hydroplanes at a central location and rotatable tail hydroplanes located, in this preferred embodiment, towards the rear of the apparatus vis a vis the flow

direction of the water.

Figure 11 is a perspective view of a tank according to the invention showing optional elongated bearings used to mount the tank to a monopile. Spaced ring bearings may also be used as shown in cross section in figure 7.

Figure 12 shows a schematic side view of a tank detailing the use of control members as water reflectors rather than hydroplanes.

Figure 13 shows a plan view of a tank according to the invention moored by cables when tidal flow in and out are at 180 degrees and moored by a monopile when tidal flow is at an angle β between inward and outward flows.

Figure 14 shows plan and cross-sectional views of apparatus for generating power from a prime mover according to the invention using a hydraulic cylinder when moored to a monopile support column.

Figure 15 is similar to figure 14 but a control/generating box is floating beneath the surface and moored by cables.

Figure 16 shows plan and cross-sectional views of apparatus for generating mechanical power from a submerged prime mover moored on a monopile support column. The apparatus can be rearranged in a similar manner to that of figure 15, ie. utilising a control/generating box submerged and moored by cables.

Figure 17 shows a schematic elevation view of apparatus for generating electricity directly using a prime mover.

Figure 18 shows a schematic elevation view of apparatus for pumping water to a higher level for storage of potential energy. Typically, the water is the same as that flowing past the tank 10.

Figure 19 shows a schematic perspective view of an alternative tank in accordance with the invention.

In figure 1, a large buoyant or floating open bottomed tank 10 contains air as a working fluid (see 17 in figure 3). Tank 10 has a substantially flat top 12 and is canoe shaped in plan view. The convex sides 14 of tank 10 meet to provide a pointed edge. The sides serve to orientate the tank so that the pointed edge points into the flow so that water passes over convex sides 14. Thus, water travels over sides 14 between points P, Q and R. At point Q the flow of water is generally homogenous and is typically faster than the flow of water at points P and R because of the constriction produced by the widening of the tank at that point. This is a suitable point at which to place hydroplanes 22 protruding from sides 14, the kinetic of the water energy available to be extracted being proportional to the cube of the velocity of the flow. Therefore the hydroplanes are advantageously located at this point of maximum velocity.

Tank 10 typically comprises a downwardly extending tube (not shown) which slidably surrounds a support column 16 secured underwater, usually to the sea of river bed 18, in an upright position. Typically, a large diameter plane bearing 20 is secured in the top of the tube and a similar bearing (not shown) is secured in the bottom of the tube so that the two bearings are widely spaced

apart. Thus, said bearings are slidable axially and rotateably relative to the column 16. Further bearing strips 20 may be provided as an alternative or in addition to the circular bearings as shown in figure 11.

Hydroplanes 22 are submerged and pivotable in their entirety, typically about a lower edge 23, about an axis generally perpendicular to sides 14 of the tank. The two upper hydroplanes 22 on opposite sides 14 of the tank are interconnected by a shaft (not shown) and the two lower hydroplanes are likewise interconnected. The inclination of the hydroplanes 22 is reversible in unison by partially rotating the associated shafts, for example by hydraulic or mechanical means. Such change in the inclination of the hydroplanes is typically under computerised control and in response to several parameters. These parameters include motion of the tank, water flow direction, forces on the hydroplanes and/or air pressure in the tank. As will be explained below, the optimum arrangement is such that air is virtually always flowing into or out of the tank. The energy within the tank at a given time is equivalent to the air pressure times the air volume. The energy available to be collected is equivalent to the volume change over a given time period times the pressure differential over the same period.

The maximum angle of inclination of the hydroplanes 22 is also adjustable. Whilst hydroplanes 22 typically act as hydroplanes causing lift by the action of water flowing over their upper and lower surfaces, control members 22 can be caused to act as water deflectors much in the same

way that a kite deflects air. This is shown in figure 12 and will be described in further detail later.

Two ducts 25 are formed in the top 12 of tank 10. These ducts house high speed air turbines and, optionally, also generators which are directly drivable by the flow of air into and out of the tank and can supply rotation directly to the electrical generators (not shown) wherever these are located. Turbines 24, and the generators, need not therefore be located underwater but are working in air enhancing reliability and ease of maintenance. Valve means (not shown) can be provided in each duct so that air passes through each turbine 24 in the same direction irrespective of the flow of air into or out of the tank. Alternatively, a special turbine such a Wells turbine is used, such turbines always turn in the same direction irrespective of the direction of air flow.

In operation, the shape and in particular the convex sides 14 of tank 10 automatically orientate it like a weather vane so that control members 22 are kept substantially at right angles to the water current indicated by arrow 26. This orientation reduces drag on the tank and increases the velocity of the current passing along particularly the widest most portion of the sides and therefore over hydroplanes 22.

The action of water current 26 on hydroplanes 22 causes the tank to move upwards and downwards on column 16 depending upon the inclination, for the time being, of the hydroplanes. Thus, the tank is caused to oscillate as indicated by arrow 32 so as to alternately compress (as it moves downwards) and decompress (as it moves

upwards) the air contained inside it between top 12 and water surface 28.

As tank 10 moves downwards the pressure differential causes air to be expelled through the ducts. During the downward part of the cycle, the downward force from hydroplanes 22 and the weight of the tank opposes the buoyancy forces, ie upthrust of the water on the tank. This can be seen in steps a and b of figure 3. The air pressure inside the tank is greater than atmospheric pressure outside and causes a small change h in the level of water inside the tank compared to the level of water outside the tank. This head of water coupled with further downward movement of the tank by virtue of the angle of inclination of the hydroplanes causes the continued pressure differential inside and outside the tank. Air 30 is expelled from the tank via ducts 25. As can be seen in figures 4 and 5, at T=T1 air commences to be expelled from the tank. This continues until T=T3 when the downward forces on the tank are balanced by the upward forces of water, head h of water is lost and the pressure inside the tank equals atmospheric pressure. At this point flow 30 ceases. It is desirable that the length of time spent at this point is kept to a minimum.

Therefore, towards the bottom of the movement and preferably before too long is spent at the bottom of the movement, the inclination of the hydroplanes 22 is caused to reverse so that these exert a vertical upward force. Tank 10 is accelerated upwards by a combination of this force and its buoyancy (see step E in figure 3).

As the tank moves upwards, the pressure within it falls below atmospheric and a small head of water h is developed compared to the level of water outside the tank. Air is drawn in through the ducts (see step F). At the top of the movement the head of water h disappears and the pressure inside the tank again reaches atmospheric.

Thus, if the distance of the tank above water surface 28 at rest is X1 and below water surface 28 is X2 then at step G, the top of the motion, X1 has increased in relation to X2.

In the measurements shown in figure 4 there is no peak in the pressure measurement to indicate air flowing in to the tank because of the limitation of the measuring equipment. Nevertheless, air was observed to flow into the tank during the period indicated.

The cycle is repeated beginning again with hydroplanes 22 being inclined in the other direction with respect to current 26.

The velocity of the air passing through the turbines can be varied by changing the size and/or the number of ducts. Thus, in figure 6, of the six ducts shown, one or more of these may be closed off or otherwise removed from the flow of air so that the velocity of air passing through the remaining ducts is increased. Thus the size and/or number of the ducts can be varied so customising a particular apparatus for a particular location (since current flows vary from location to location)or for particular conditions. Indeed, several ducts can be

diverted through a single turbine, so that it operates in its most effective range for power generation, when water flow is slow, and rediverted to several ducts (and hence several turbines) when water flow is fast. Typically, the air turbines also comprise a generator located in the ducts. The velocity of air passing through the turbines can also be varied by changing the number and/or size of the hydroplanes. This ability to customise the tank to location and the prevailing conditions allows it to operate at optimum or near optimum efficiency in given circumstances.

Since the tank 10 floats and is slidable relative to column 16 it is self-adjusting to changes in the height of water surface 28. Furthermore, since it can rotate on monopile 16 it is self-adjusting to changes in the direction of water flow. This can be particularly important for tidal flows where inward and outward tidal flows are not at approximately 180 degrees to each other. This is shown in detail in figure 13 in which cables 33 can be used to moor tank 10 on monopiles 25 when inward and outward flow are in substantially opposite directions or in river flows. A limited amount of rotation can be possible when using mooring cables if the attachment points of the cables are designed for this. However, a central monopile 16 is typically used to mount tank 10 when inward and outward flows are at angle β with respect to one another. This allows rotation of tank 10 by angle β to align itself with the prevailing tidal flow.

The angle of inclination of the hydroplanes relative to the direction and speed of the water current governs the

magnitude of lift and drag forces on the tank. Thus, typically control members 22 function as hydroplanes acting as hydroplanes generating lift but little drag. In figure 12, water flow 26 is redirected downwards by control member 22d causing tank 10 to move in the direction of arrow 32. This is similar to the way that a kite maintains it height. Control member 22D is rotated through a vertical plane about a horizontal axis to cause the tank 10 to reverse its direction of motion. Control members 22D can however cause drag so their use may be limited to particular circumstances where drag is not a problem, such as when firm cable moorings are available.

Adjustment of the angle of hydroplanes or control members 22d such as those in figure 12 can allow for maximum power output over a wide range of current speeds. Thus there are several variables as described above which can be optimised to increase the efficiency and power output of the apparatus. Furthermore, the apparatus can be connected to shore by a power cable and can be submersible during storms thereby reducing the risk of damage.

Figure 6 shows control members 22C and 22B which typically function as hydroplanes operating over an angular range of 5 to 30 degrees, for example, 2α equals around 60 degrees. The frequency with which the planes are reversed is typically 5 to 20 seconds, but may be less than or more than this. The angular orientation of the hydroplanes in a working position is selected from a range of angular working positions.

Hydroplanes 22a are located on the widest portion of tank 10. Alternative or further hydroplanes 22B and 22C can be located at other points though this is less preferred. Hydroplanes 22B are equally spaced whereas hydroplanes 22c are not equally spaced. By locating hydroplanes in a vertical direction, one above the other, roughly perpendicular to the water flow the turbulence flow produced downstream does not interfere with its neighbours. Thus, typically one of the series 22A and 22B and 22C, is selected rather than having hydroplanes spaced along the tank in the direction of flow of the water. The hydroplanes may be staggered, i.e. spaced vertically but overlapping in a horizontal direction such as hydroplanes 22E in figure 8.

Figure 8 also shows a tank similar to that in figure 6 and 7 but moored by cables 33 to a suitable mooring point either above or below water level. Figure 9A shows two symmetrical cross-sections, one more aerodynamic than the other, for use as hydroplanes and one aerofoil cross-section for use as hydroplane. Typically, symmetrical shapes are preferred and aerodynamic shapes are preferred most of all.

Figure 10 shows fixed hydroplanes 22 which do not rotate with respect to member 10. Rotatable tail hydroplanes 34 cause the tank to rise or fall. Once this rise has begun, it slightly tilts the tank so that hydroplanes 22 are now at an angle with respect to water flow 26 thus adding to the forces causing the tank to rise or fall. Other hydroplanes, or mounting structures, fixed with respect to the tank on which reversible hydroplanes are mounted

may be used. These resemble pivotal flaps on aeroplane wings. A further type of hydroplane suitable for use with the invention is shown in Fig. 9B. Here, hydroplane 22F shown in cross section is flexible and can be flexed so that its curvature is inverted (reversed) causing lift 32A or downward thrust 32B as appropriate.

Figures 14 to 18 show the use of a prime mover 40 mounted about a monopile 16 or moored via cables 33 and provided with hydroplanes 22 causing prime mover 40 to rise or fall on the reverse of these hydroplanes. Several different kinds of power conversion means are provided for converting the oscillating motion of prime mover 40 into usable forms of power, whether this is water stored at a higher level, mechanical rotation, electrical power, hydraulic power and so on. Whist tank 10 is typically buoyant, prime mover 40 is typically partially buoyant so that it is submerged when at rest. Prime mover 40 rises and falls in exactly the same way as tank 10 by reversing the inclination of hydroplanes 22 or control members 22D as previously described. Thus, prime mover 40 oscillates up and down in the direction of arrow 32.

In figure 14, a hydraulic piston pumps fluid within a control chamber 40 to generate power or connects to a crank

In figure 15 a similar hydraulic pump 42 is used though in this case control chamber 44 is located beneath the surface and is moored to the sea bed by cables 33. Thus, the prime mover 40 here floats above the sea bed. Typically column 16A, about which prime mover 40 is located, comprises slots through which members mounted on

prime mover 40 project to drive pump 42 so causing the piston in hydraulic apparatus 42 to rise and fall. Also column 16A is open to the surface to permit access to the control and generating chamber 44 and so that power can be extracted for example by cables.

In figure 16 shaft 42a rises and falls causing a crank system 43 to generate mechanical rotation which can be converted into electrical power or caused to drive a turbine.

In figure 17 struts 46 carry a coil 48 and move up and down in the direction of arrow 32 along with prime mover 40. Coil 48 is positioned about a magnet 50 to provide directly an ac current directly.

In figure 18, water is pumped by hydraulic apparatus 42 and pipe 52 into an elevated storage chamber 54. The water falls back via pipe 56 and can be used to generate electrical power in water turbine 58.

In figure 19, an alternative embodiment uses rotating cylinders to generate upward and downward thrust. Cylinders 61 rotate in the direction of arrow 62 with respect to current 26. The cylinders produce drag 62 but also a downward force 60, or an upward force when rotation is reversed. Whilst rotation may be produced by driving connecting rod 64 using electricity, current 26 may be used to provide the necessary rotation via rotating wheel 70 which via connecting means 68 and gear box 66 causes rod 64 to rotate. A windmill type wheel rotating about a horizontal axis (not shown) could also be used. The gear box could be used to produce the

reversal in rotation 63 without changing the direction of motion of rotating wheel 70.

Thus, the invention provides not only an apparatus for converting slow moving water or other suitable fluids (both gases and liquids) into fast moving air so that rotational speeds of 1,000 to 3,000 revolutions per minute in turbines can be generated, but also prime movers which can be combined with any appropriate energy removal system. Suitable liquids or other gases can be used in place of air. The fast moving fluid is typically lighter than the fluid from which power is extracted. The tank can be non-buoyant or of neutral buoyancy. The tank or prime mover can be orientated by power driven means instead of like a weather vane. One or more rudders or other vertical control surfaces may be provided to aid the orientation of the tank. These may be power driven but could be manually set for example on each tide change. The tank and the prime mover can be located permanently under water. The tank can have a shape different from that shown. A single tank or several tanks may be used.

The apparatus can be used to provide power for an associated desalination plant. One further arrangement is for a combined apparatus responsive to tidal flows, waves and windpower is provide. For example, a wind turbine mounted on top of a support column could be used. Thus power generation is derivable from the action of wave energy on the prime mover, especially when the prime mover is a tank, tidal flows on the prime mover and wind power from the wind turbine mounted on top of the support

column. Power generation is possible from the action of waves on one of the control surfaces providing resistance to the bobbing motion of the tank under the influence of the waves. Power generation from waves incident on the semi buoyant collector cause the water inside the collector level to rise and fall relative to the top of the collector. Vertical movement of the collector is damped by the drag of the hydroplanes. The force of the moving water in the wave cycle pushing against the hydroplanes can cause the collector to move in opposite phase to the water inside the collector so causing the fluid in it to be alternately compressed and decompressed. The angle of the hydroplanes can be altered to increase this effect of the waves passing into the collector. The apparatus can incorporate means for storage of energy or can be used to provide power for an autonomous device such as a buoy. A further embodiment may include two prime movers such as tanks 10 with one or more hydroplanes extending between the prime movers. This offers stability to the hydroplanes since both ends of each hydroplane are supported by the tanks.

Control members in the form of hydroplanes and rotating cylindrical structures (whether hollow, solid or vanes spaces about roughly cylindrical periphery and so on) can be used in combination on a prime mover of the invention. The prime mover may be arranged to oscillate horizontally. The angle of inclination, need not be the same for the upward and downward parts of this cycle (eg to take account of the weight of the prime mover).

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CLAIMS

1. A prime mover for extracting power from a current of water comprising:

a body;

a control member protruding from a side of the body and adapted for submersion in the current of water to generate thrust;

means for periodically reversing the direction of the said thrust, causing the body to oscillate; and

means for extracting power from the oscillatory movement of the body.

2. A prime mover according to claim 1 in which at least one control member protrudes from each side of the body.

3. A prime mover according to claim 1 or 2 in which the shape of the body is such that water is caused to travel faster over a portion of the surface of the body and in which one or more protruding control members are positioned at that portion of the surface of the body.

4. A prime mover according to claim 3 in which the body comprises curved sides which orientate the body with respect to the current of water so that the control member or members are substantially perpendicular to the direction of the current.

5. A prime mover according to any proceeding claim in which the shape of the sides is symmetrical.

6. A prime mover according to claim 3, 4 or 5 in which the sides of the body are convex.

AMENDED SHEET

7. A prime mover according to any preceding claim in which at least one second protruding control member is provided fixed with respect to the body and arranged so that when the direction of thrust of a first reversible protruding control member is reversed, the angle of the second fixed control member with respect to the current of water is altered so that the action of the water on that second fixed member causes the body to oscillate.

8. A prime mover according to claim 7 in which the fixed second control member is positioned at a point on the body at which the velocity of the water current flowing past the body is at or near a maximum and the first reversible control member is spaced laterally from it in the direction of the water current.

9. A prime mover according to any preceding claim in which one, or more control members comprise hydroplanes whereby the direction of thrust is reversed by the angle of inclination of at least one hydroplane.

10. A prime mover according to any preceding claim in which one or more reversible control members is pivotable in its entirety.

11. A prime mover according to any preceding claim in which one or more reversible control member is pivotable about an edge of that member protruding from the body.

12. A prime mover according to any preceding claim in which one or more reversible control members is pivotable about a centrally located axis protruding from the body

and passing through the member.

13. A prime mover according to any preceding claim in which one or more of the reversible control members are formed by pivotable flaps mounted to a control member or other mounting means fixed with respect to the body.

14. A prime mover according to any preceding claim in which one or more reversible control members have an aerofoil shape.

15. A prime mover according to any preceding claim in which one or more control members comprise a rotatable cylindrical structure, the direction of rotation of which can be reversed so as to cause a change in the direction of thrust generated.

16. A prime mover according to any preceding claim in which the distribution of control members on opposing sides of the body is symmetrical.

17. A prime mover according to any preceding claim in which the body is elongate and tends to orientate itself so that it is elongate in the direction of the current.

18. A prime mover according to any preceding claim in which the body oscillates in a vertical direction.

19. A prime mover according to any preceding claim in which more than one control member is provided on opposing sides of the body.

20. A prime mover according to claim 19 in which the

control members are spaced along the body in a direction substantially perpendicular to the direction of the current when the body is orientated so that its control members protrude from the body in a direction substantially perpendicular to the direction of the current.

21. A prime mover according to claim 20 in which the body is arranged to oscillate vertically and two or more control members are provided on opposing sides of the body in a substantially vertical line.

22. A prime mover according to claim 20 or 21 in which three or more control members are provided on each side and the separation of the control members is substantially equal.

23. Apparatus for extracting power from moving water comprising a prime mover according to any preceding claim.

24. Apparatus according to claim 23 in which the prime mover is connected to mooring means secured or securable under water.

25. Apparatus according to claim 23 or 24 in which the prime mover is connected to mooring cable.

26. Apparatus according to any of claims 23 to 25 in which the prime mover is axially slidably mounted or mountable to a column secured or securable under water in an upright position.

27. Apparatus according to claim 26 in which the prime mover comprises a downwardly extending tube which surrounds the column.

28. Apparatus according to any of claims 23 to 27 in which the prime mover is submerged when generating power.

29. Apparatus according to any of claims 23 to 28 in which power conversion means are provided comprising one or more hydraulic pumps, a crank arrangement, or means for generating electricity, such as an electric coil and magnet.

30. Apparatus according to any of claims 23 to 28 in which power conversion means are provided comprising a fluid pump for pumping fluid to a higher level to store potential energy.

31. Apparatus according to any claims 23 to 30 moored to or mounted on a structure such as a column on which apparatus for extracting power from wind is mounted.

32. Apparatus according to any of claims 23 to 31 in which the prime mover is buoyant.

33. Apparatus according to any of claims 23 to 32 in which the prime mover comprises an open bottomed tank which when it oscillates alternately compresses and decompresses a fluid inside it between a closed top of the tank and the water surface.

34. Apparatus according to claim 33 in which at least one duct in the top of the tank permits the fluid

alternately to flow out of and into the tank.

35. Apparatus according to claim 34 in which the fluid flowing through one or more ducts drives a turbine.

36. Apparatus according to claim 35, in which two or more ducts are provided and the number of ducts selected can be varied and/or in which the size of one or more ducts can be varied.

37. Apparatus according to claim 35 or 36 in which a turbine is housed in a duct.

38. Apparatus according to any of claims 36 to 37 in which the turbine rotates in the same direction irrespective of the flow of fluid out of or into the tank.

39. Apparatus according to any of claims 35 to 37 in which valve means are provided so that fluid passes through the turbine in the same direction irrespective of the flow of fluid out of or into the tank.

40. Apparatus according to any of claims 34 to 39 in which the turbine is directly drivably connected to an electrical generator.

41. Apparatus according to any of claims 33 to 39 in which the fluid is air.

42. A method for extracting power from a current of water using a prime mover as claimed in claim 1, comprising periodically reversing the direction of thrust

generated by the said control member, using the means provided for that purpose.

43. A method according to claim 42, in which the control member comprises a hydroplane whose angle of inclination can be reversed.

44. A method according to claim 42, in which the control member comprises a rotating cylindrical member whose direction of rotation can be reversed.

45. A prime mover substantially as described herein with reference to and/or as illustrated in the accompanying figures.

46. Apparatus for extracting power from moving water substantially as described herein with reference to and/or as illustrated in the accompanying figures.

47. A method for extracting power from moving water substantially as described herein with reference to and/or as illustrated in the accompanying figures.

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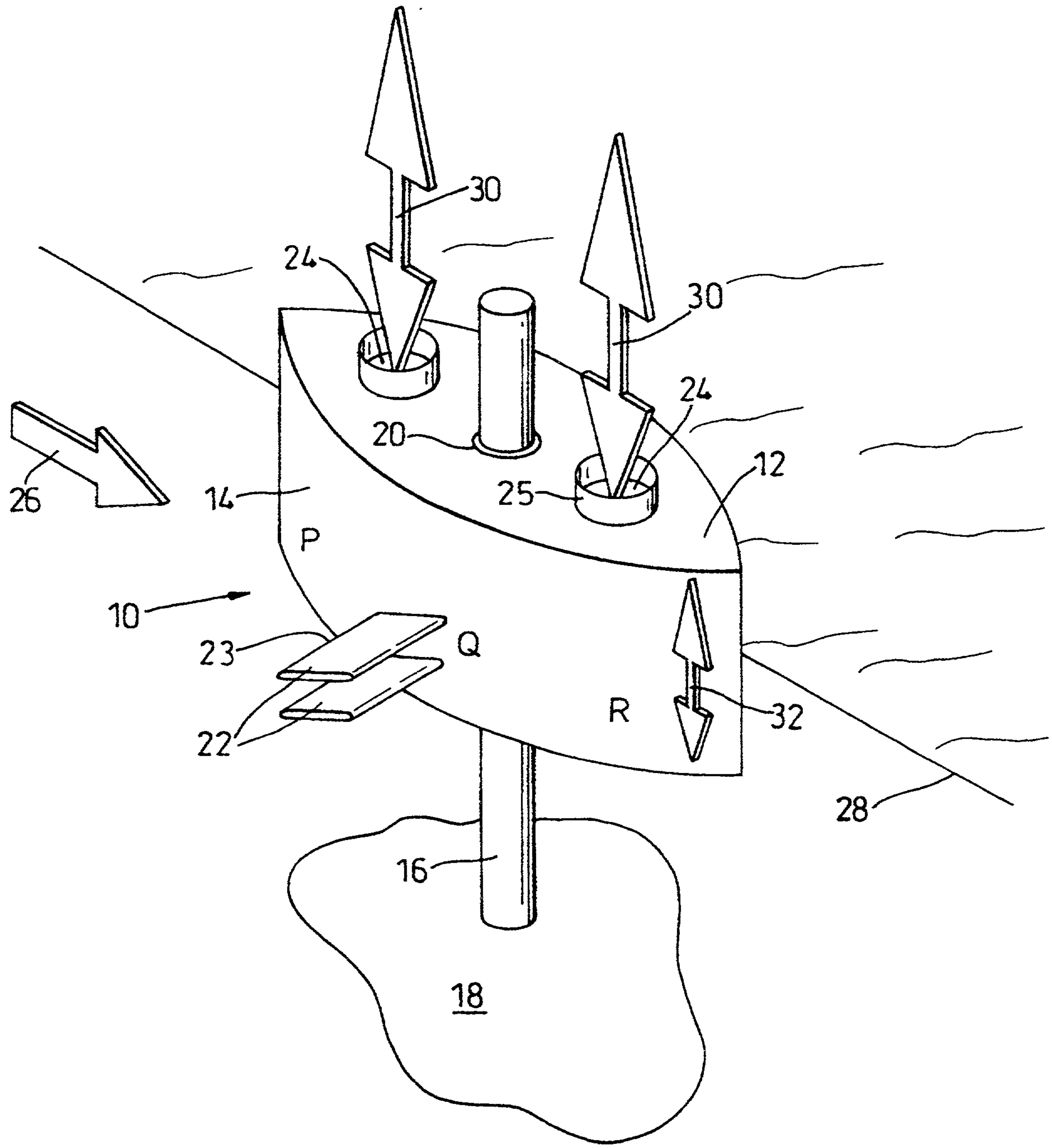

Fig. 1

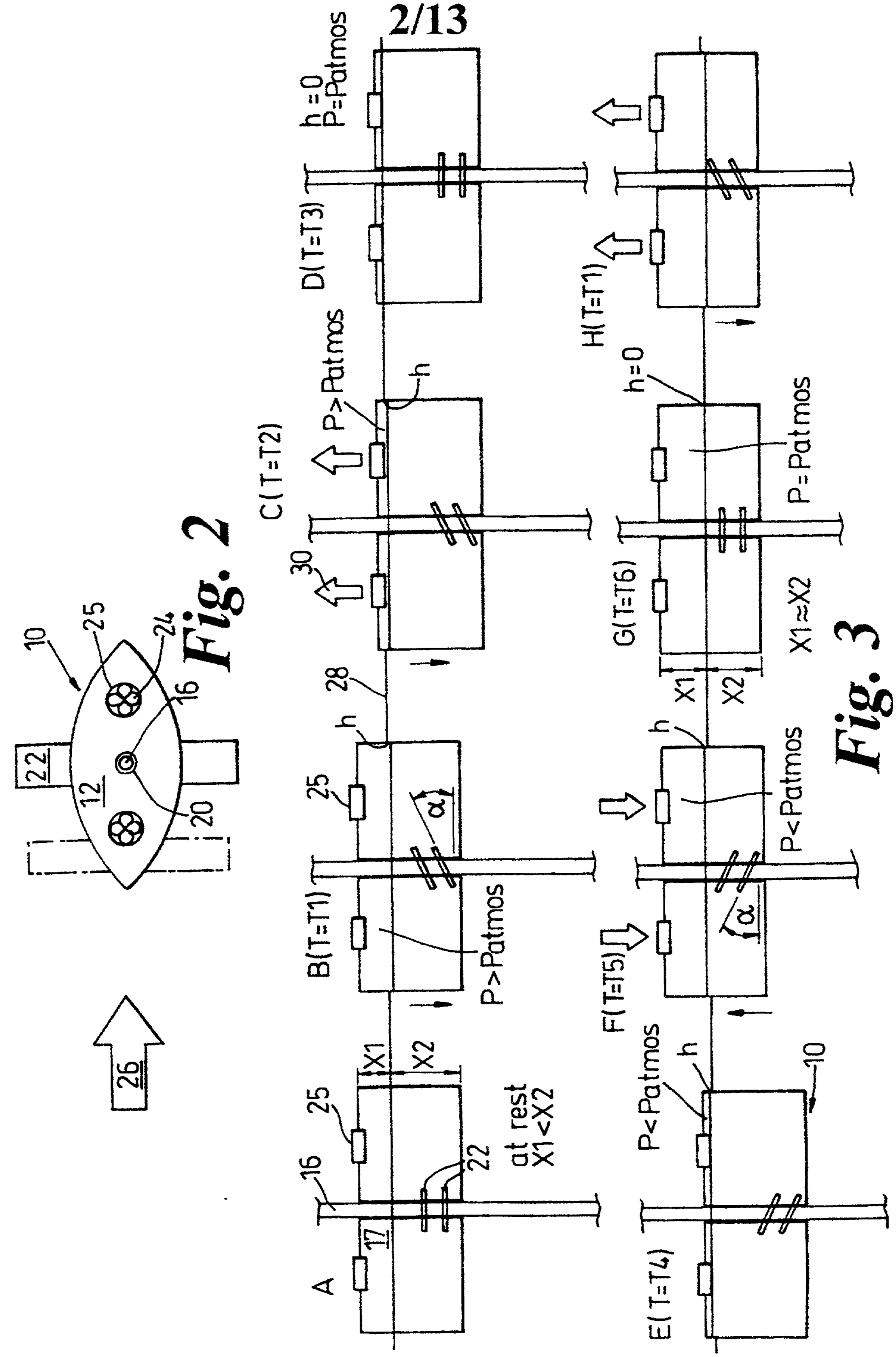
A
B(T=T1)
C(T=T2)
D(T=T3)
E(T=T4)
F(T=T5)
G(T=T6)
H(T=T1)
h=0
P=Patmos
P>Patmos
P<Patmos
P=Patmos
at rest
X1<X2
X1≈X2
X1
X2
h
α
10
12
16
17
20
22
24
25
26
28
30

Fig. 2

Fig. 3

Run: Blytha03, oscillation period 2.8 sec, exit diameter 100mm (1% of collector surface), tow 0.94 m/sec, rotation 41 deg in 1 sec.

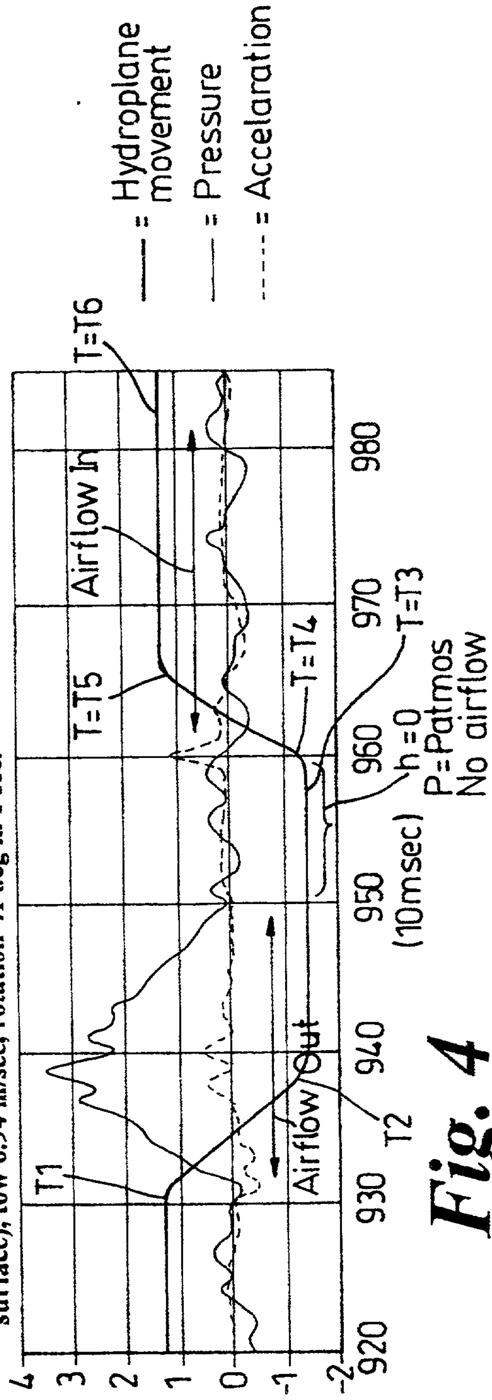

Fig. 4

Run: Blytha03, oscillation periods 4.2 & 2.8 sec, exit diameter 100mm (1% of collector surface), tow 0.94 m/sec, rotation 41 deg in 1 sec.

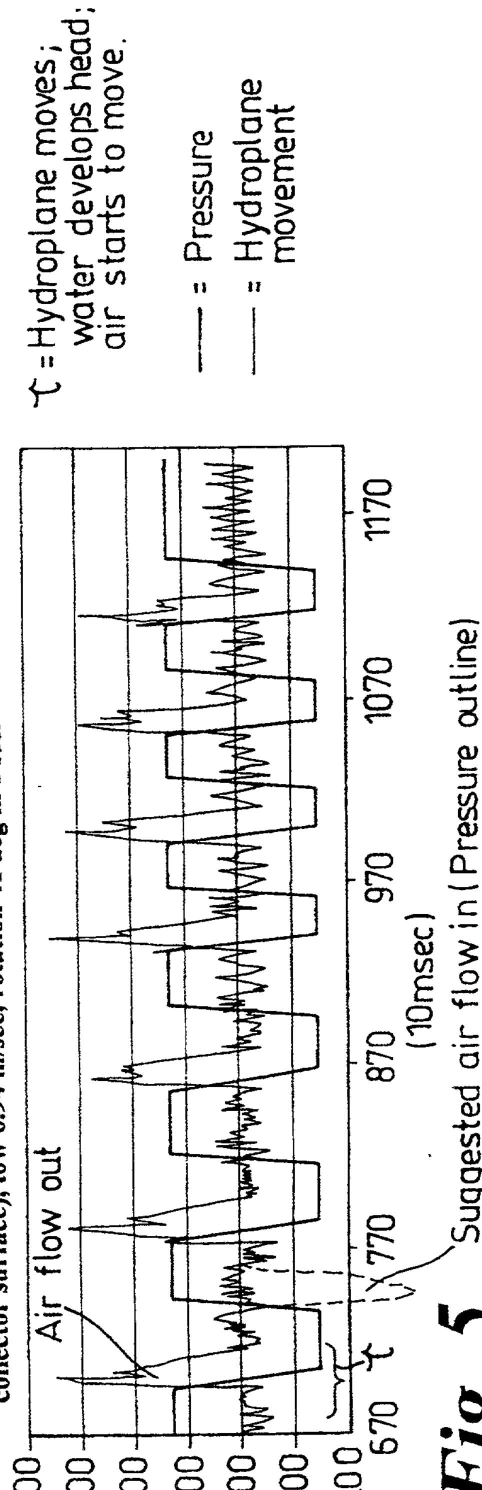

Fig. 5

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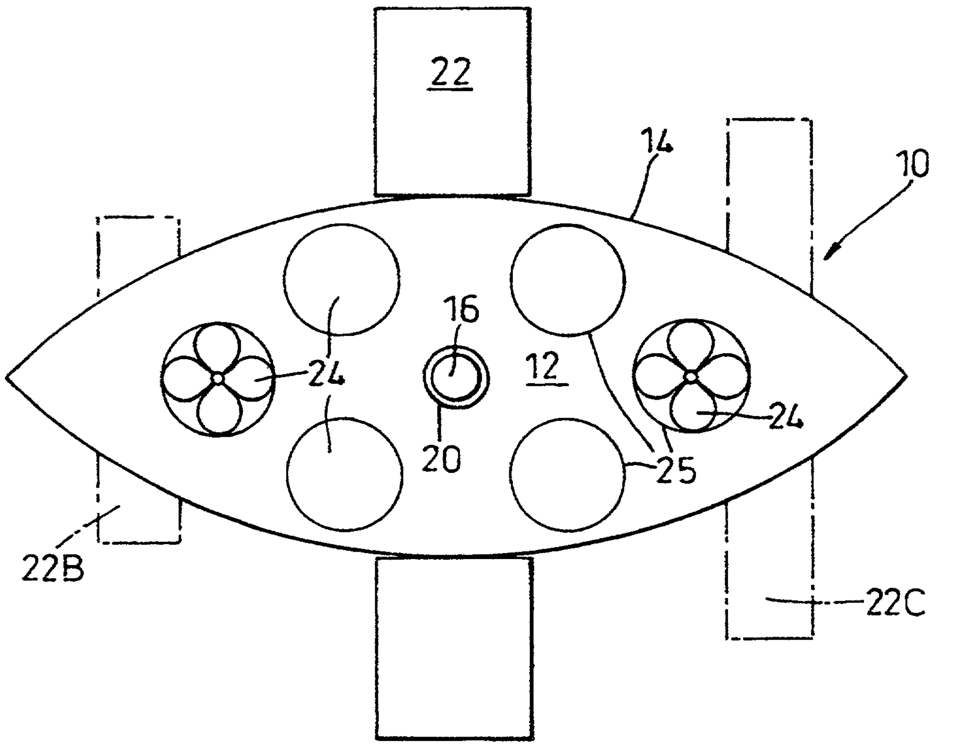

Fig. 6

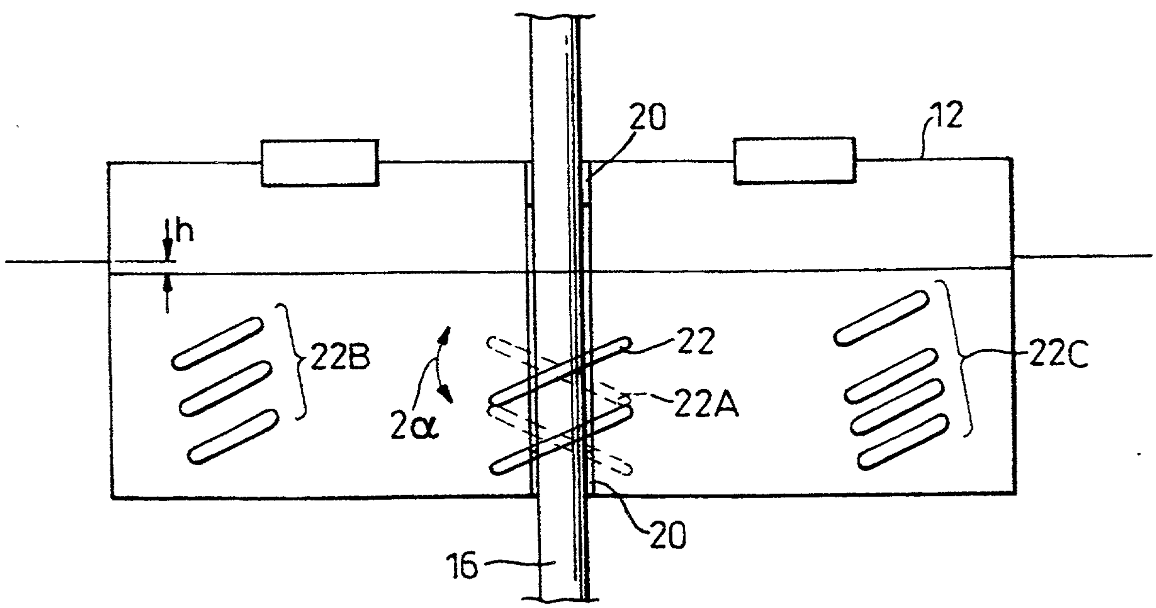

Fig. 7

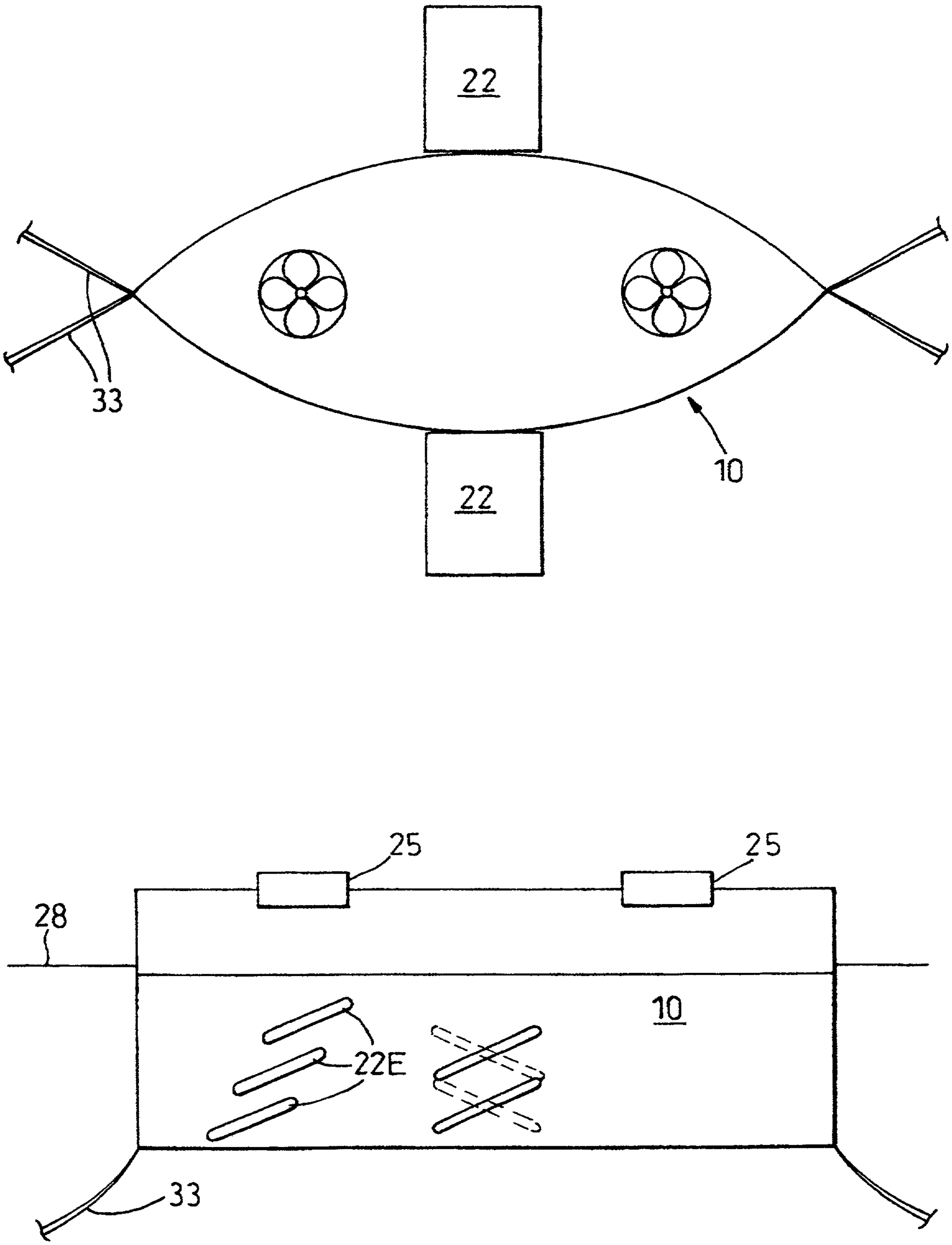

Fig. 8

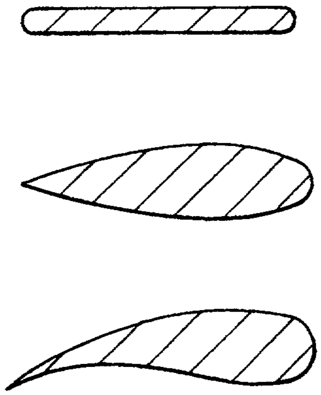

Fig. 9A

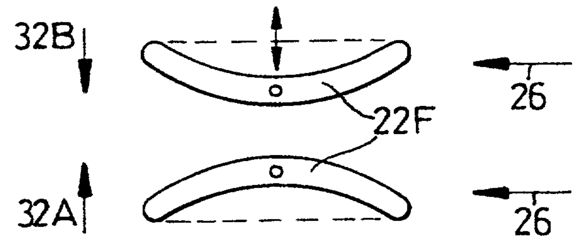

Fig. 9B

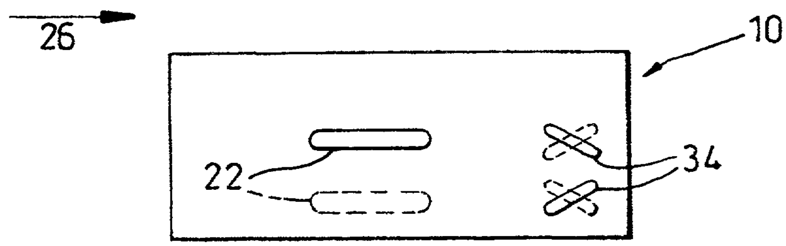

Fig. 10

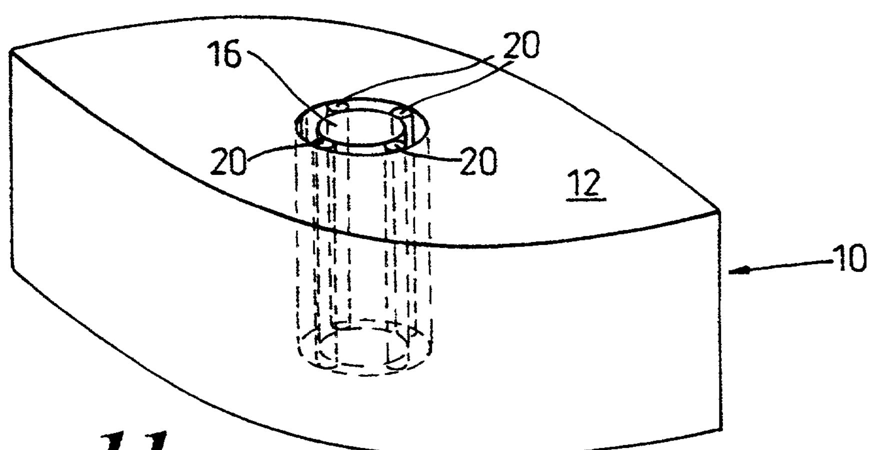

Fig. 11

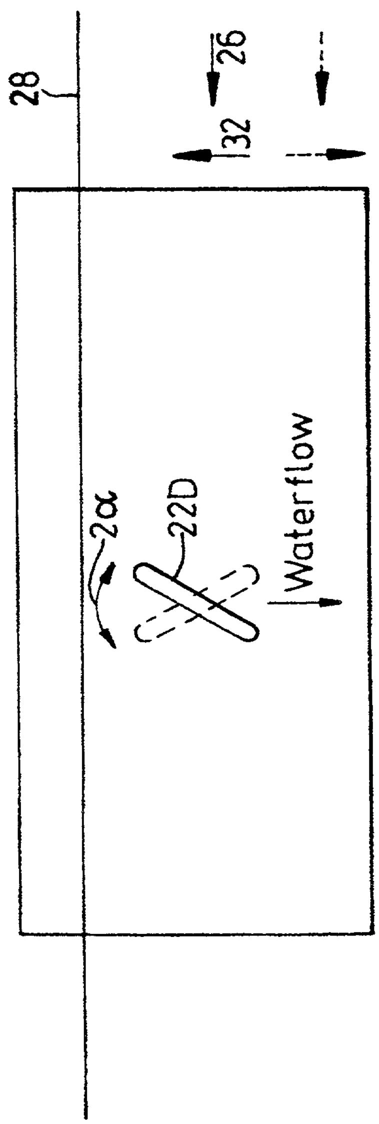
28
26
32
2α
22D
Waterflow

Fig. 12

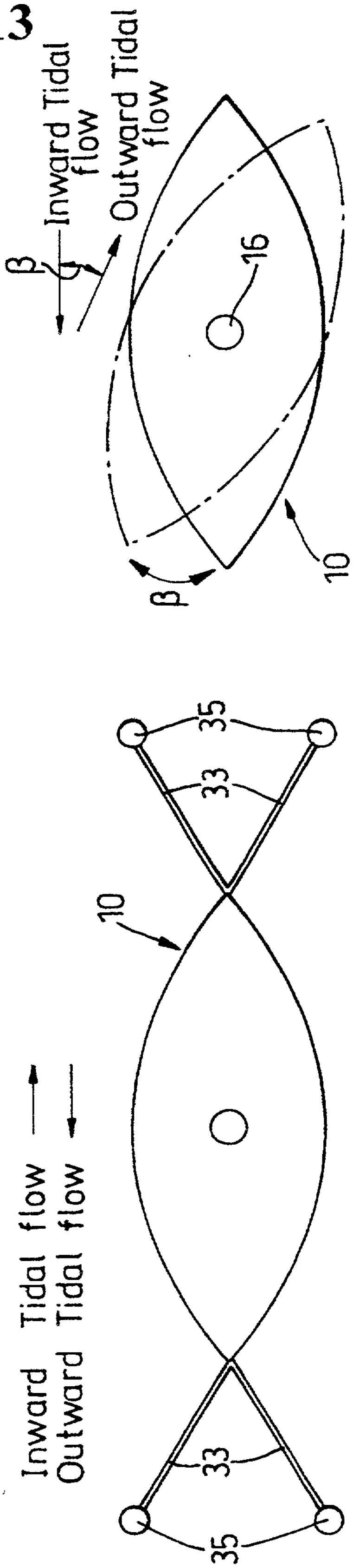
Inward Tidal flow
Outward Tidal flow
β
16
10
β
Inward Tidal flow
Outward Tidal flow
35
33
10
33
35

Fig. 13

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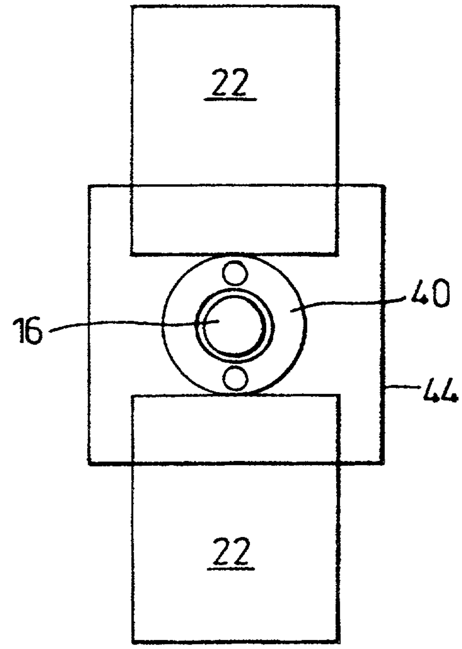
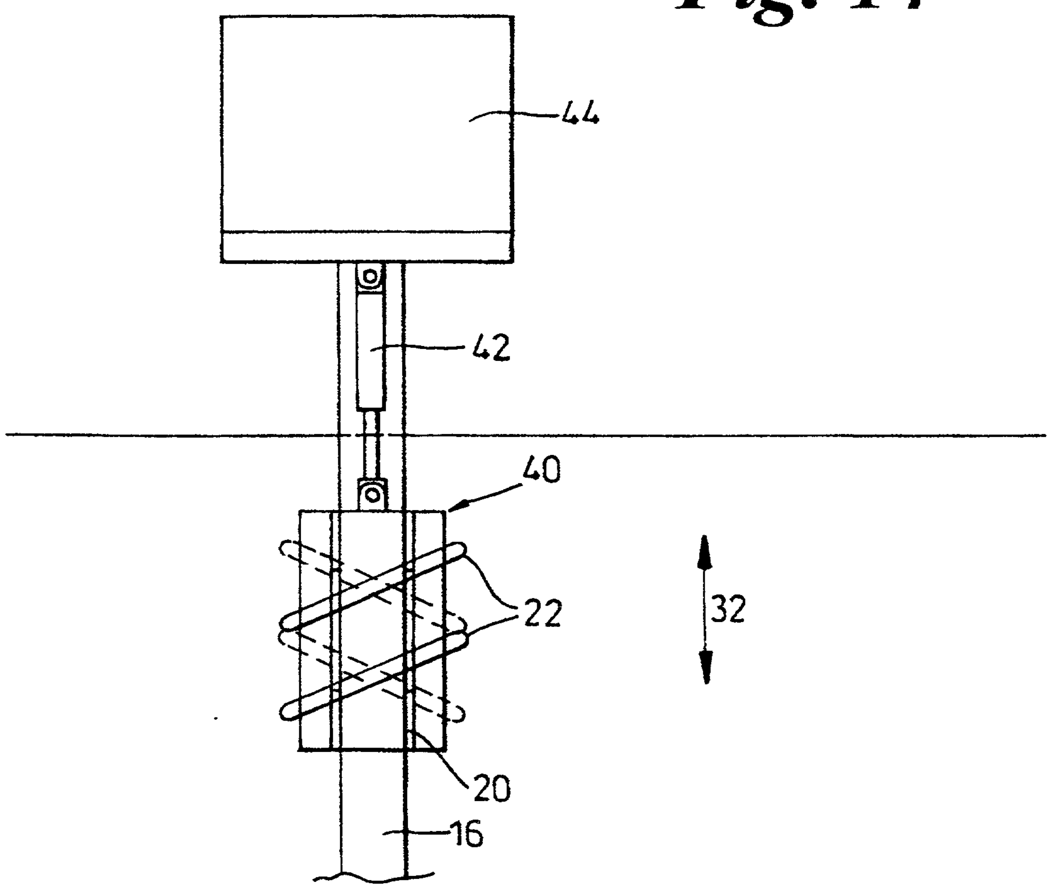
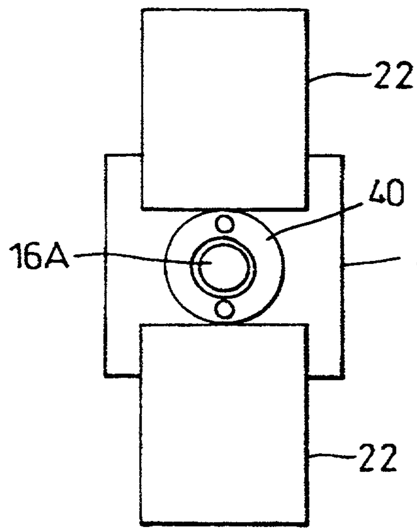


Fig. 14





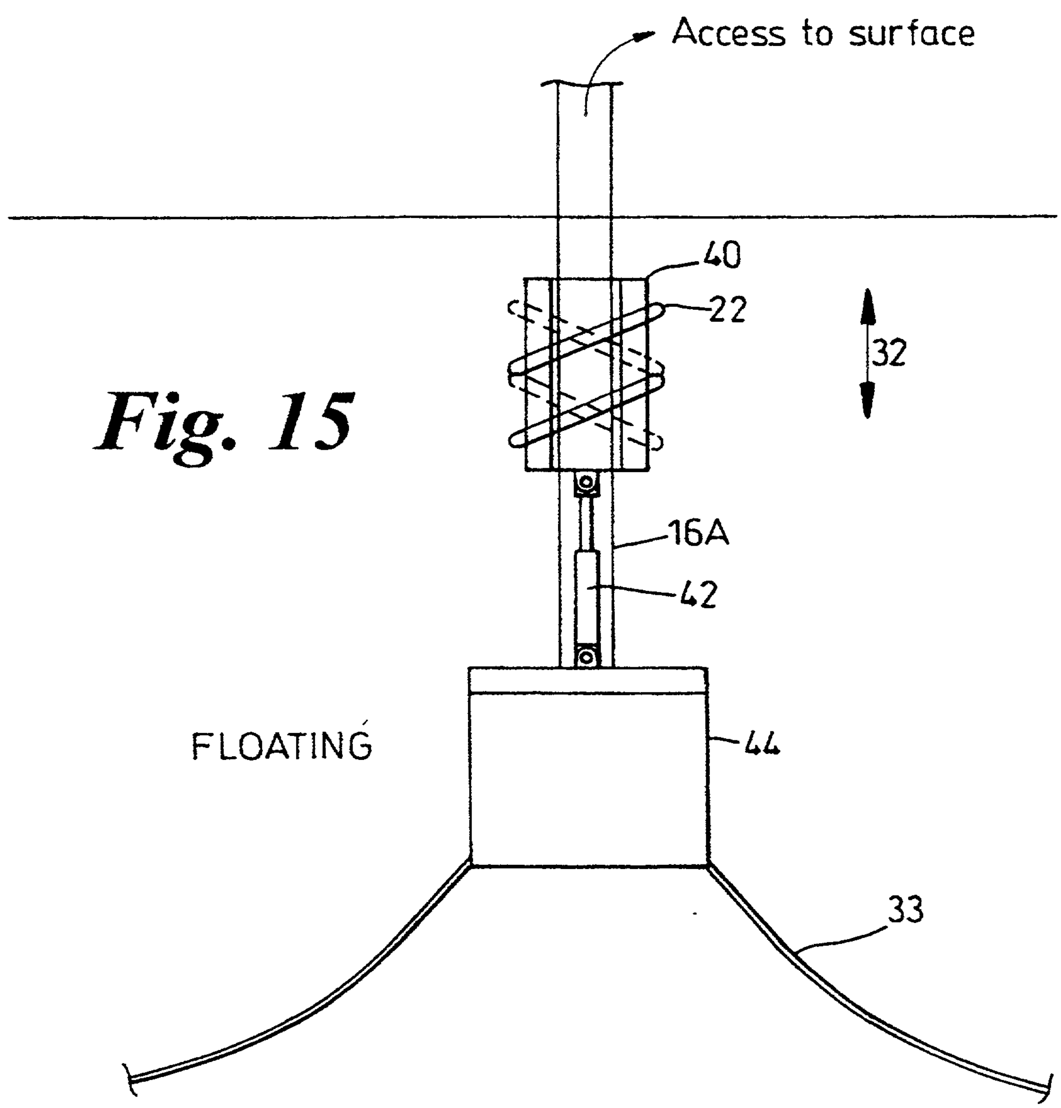


Fig. 15

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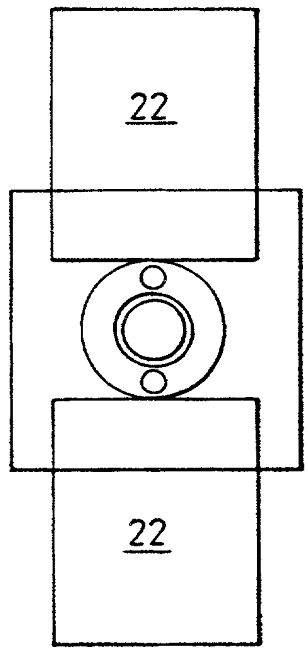


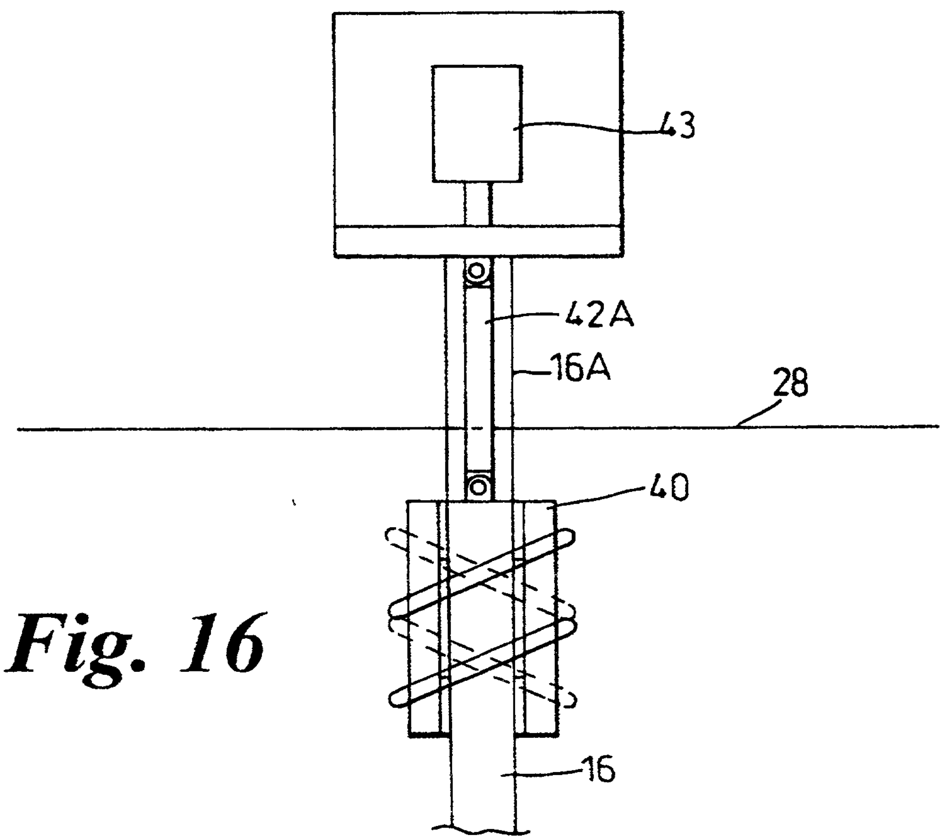


Fig. 16

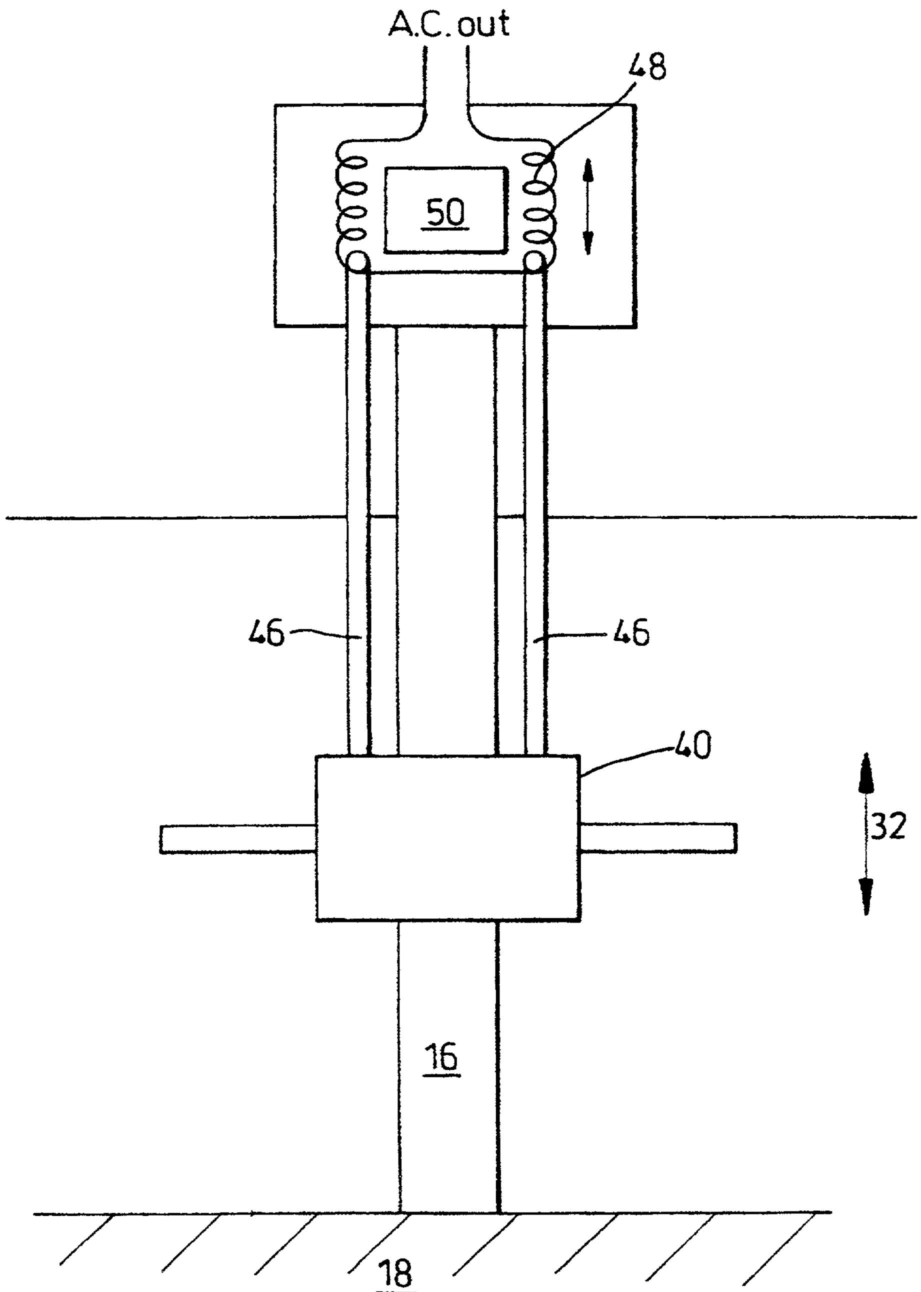


Fig. 17

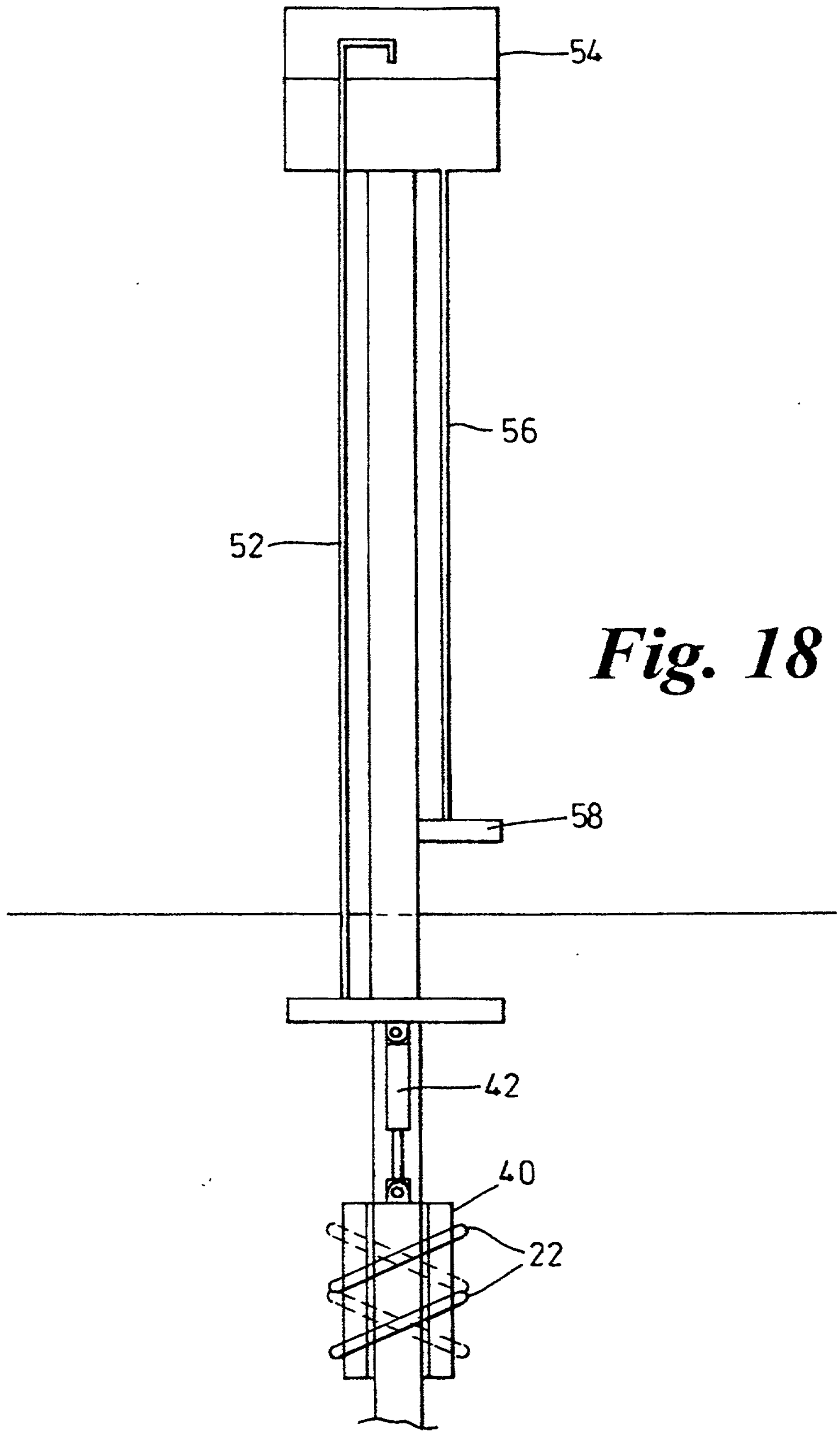
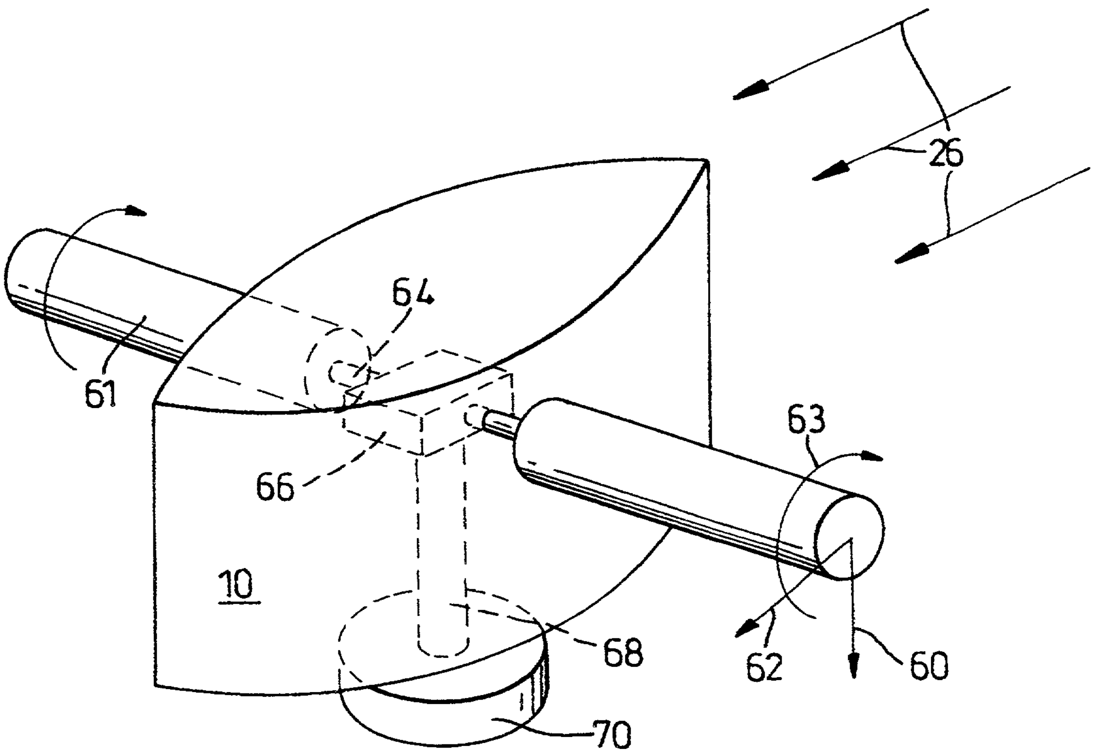


Fig. 18



Reverse Rotation to Reverse Force Direction

Fig. 19

A, F, K, P & K Docket No. P108149-00000 ARENT FOX KINTNER PLOTKIN & KAHN PLLC

Declaration For U.S. Patent Application

As a below named inventor, I hereby declare that:
My residence, post office address and citizenship are as stated below my name.
I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention **entitled**
(Insert Title) EXTRACTING POWER FROM MOVING WATER
the specification of which is attached hereto unless the following box is checked:

☒ was filed on March 5, 1999 as PCT International Application Number PCT/GB99/00573 and was amended on ___ ______.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claim(s), as amended by any amendment referred to above.
I acknowledge the duty to disclose information which is material to patentability as defined in 37 C.F.R. §1.56.
I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate or PCT International Application having a filing date before that of the application(s) for which priority is claimed:

(List prior foreign applications. See note A on back of this page)				Priority Claimed
	9804770.7 (Number)	GB (Country)	7 March 1998 (Day/Month/Year Filed)	☒ Yes ☐ No
	(Number)	(Country)	(Day/Month/Year Filed)	☐ Yes ☐ No
	(Number)	(Country)	(Day/Month/Year Filed)	☐ Yes ☐ No

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below.

(Application Number)	(Filing Date)
(Application Number)	(Filing Date)

(See Note B on back of this page) ☐ See attached list for additional prior foreign or provisional applications.

I hereby claim the benefit under 35 U.S.C. §120 of any United States application(s) or §365(c) of any PCT International application(s) designating the United States of America listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior application(s) (U.S. or PCT) in the manner provided by the first paragraph of 35, U.S.C. §112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 C.F.R. §1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

(List prior U.S. Applications or PCT International applications designating the U.S.)			
	(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
	(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)

And I hereby appoint as principal attorneys: Robert B. Murray, Reg. No. 22,980; David T. Nikaido, Reg. No. 22,663; Charles M. Marmelstein, Reg. No. 25,895; George E. Oram, Jr., Reg. No. 27,931; Douglas H. Goldhush, Reg. No. 33,125; Monica Chin Kitts, Reg. No. 36,105; Richard J. Berman, Reg. No. 39,107; King L. Wong, Reg. No. 37,500; James A. Poulos, III, Reg. No. 31,714; Murat Ozgu, Reg. No. ~~44,275; Brad~~ley D. Goldizen, Reg. No. 43,637; N. Alexander Nolte, Reg. No. 45,689; Robert K. Carpenter, Reg. No. 34,794; Gregory B. Kang, Reg. No. 45,273; Rustan J. Hill, Reg. No. 37,351; Rhonda L. Barton, Reg. No. P47,271; Carl Schaukowitch, Reg. No. 29,211; and Kevin F. Turner, Reg. No. 43,437.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

(See Note C on back of this page) 100

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Inventor's signature T.W. Grinsted 15-9-00 Date
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Rev. #15 1/14/00

2-00

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Inventor's signature M. J. Watc 15-9-00 Date

Residence: The Old Coach House, High Mickley Stocksfield, Northumberland NE43 7LU United Kingdom GBX

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